Observations, Analysis, and Orbital Calculation of the Visual Double Star STTA 123 AB

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Abstract: As part of a research workshop at Pine Mountain Observatory, four students from Evergreen State College met with an instructor and an experienced double star observer to learn the methods used to measure double stars and to contribute observations to the Washington Double Star (WDS) Catalog. The students then observed and analyzed the visual double star STTA 123 AB with few past observations in the WDS Catalog to determine if it is optical or binary in nature. The separation of this double star was found to be 69.9" and its position angle to be 148.0°. Using the spectral types, stellar parallaxes, and proper motion vectors of these two stars, the students determined that this double star is likely physically bound by gravity in a binary system. Johnson calculated a preliminary circular orbit for the system using Newton's version of Kepler's third law. The masses of the two stars were estimated based on their spectral types (F0) to be 1.4 M☉. Their separation was estimated to be 316 AU based on their distance from Earth (about 216.5 light years) and their orbital period was estimated to be 3357 years. Arnold compared the observations made by the students to what would be predicted by the orbit calculation. A discrepancy of 14° was found in the position angle. The authors suggest that the orbit is both eccentric and inclined to our line of sight, making the observed position angle change less than predicted.

Introduction

This project was part of the 2010 Pine Mountain Observatory Summer Research Workshop. The students chose to study double stars because the concepts are relatively straight forward and they offer swift publication opportunities (Johnson 2008). Double star observations also have a long legacy, drawing from a large pool of individual contributors over the course of hundreds of years. The students from Evergreen State College—a school whose ethos is founded on cooperative learning—believed it was in their interest to participate in these ongoing collaborations.The aim of this project was three fold: to contribute observations of double stars to the Washington Double Star (WDS) Catalog, to learn the procedure for double star observation, and to study a dou-

Figure 1: Left to right: Jo Johnson, Nick Brashear, Angel Camama, Miles Drake, Miranda Smith. The NexStar 6 SE telescope used in the project is in the center.

ble star to determine whether it is optical or binary. If the double star was found to be binary, the participants would calculate a rough orbit.

The participants employed an equatorial-mounted Celestron NexStar 6 SE telescope, which was fitted with an illuminated Celestron Micro Guide eyepiece. A digital stopwatch that read out to the nearest 0.01 seconds was used to find the scale constant of the linear scale in the eyepiece. All observations were made at Pine Mountain Observatory near Bend, Oregon on the nights of August 5 and 6, 2010 (B2010.594).

Methods

The participants polar aligned the telescope. The linear scale in the Micro Guide eyepiece was calibrated by observing the star Navi in the constellation Cassiopeia. Navi was selected for its reasonable brightness and favorable declination (60.717º). Stars with declinations above 70° move too slowly and stars below 45° move too quickly. The observers allowed Navi to drift down the linear scale by disabling the tracking motors. Ten drifts were timed with a stopwatch and the standard deviation and standard error of the mean were calculated.

The scale constant was calculated by multiplying the average time (101.99 seconds) by the sidereal rate of the Earth's rotation (15.0411 arc seconds per second) and the cosine of the declination. This was then divided by the number of divisions on the linear scale (60). This equation yielded a scale constant of 12.50 arc seconds per division. The standard deviation and standard error of the mean of these results were calculated to be 1.1 and 0.3 arc seconds per division, respectively.

The angular separation between the primary and secondary stars was determined by carefully orienting the telescope so that one of the major divisions of the linear scale was between the two stars. The distance from the major division to each of the stars was estimated in minor divisions to one tenth of a minor division. Ten trials were performed (one of them was discarded as an outlier). The average, standard deviation, and standard error of the mean were calculated.

The second parameter of double star measurement is the position angle, the angle that the primary and secondary stars make relative to celestial north. The observers chose to use the drift method as it is the most precise without adding an external protractor (Baxter 2010). This was carefully done by aligning the primary star, using the slow motion controls, with the central division of the linear scale while telescope tracking was active. Once the star was aligned with the center of the linear scale, the telescope's automatic tracking was disabled. The primary star then drifted across the inner protractor built into the eyepiece. The angle the star crossed was noted and recorded. An angle of 90° had to be added for the Celestron Micro Guide eyepiece correction (Teague 2004). Position angle measurements were repeated five times for the first double star (61 Cyg) and ten times for the second (STF 123AB). Observations were limited by smoke from a nearby fire which obscured the stars.

Observations

The observers first selected a well known double star, 61 Cygni (STF 2758 AB), to learn the measurement methods. Table 1 gives the observational results.

Table 1: Average, standard deviation, and standard error of the mean for the observed separation and position angle of 61 Cygni.

	Separation	Position Angle
Average	32.2″	151.4°
Standard Deviation	2.1″	1.5°
Mean Error	0.7″	0.4°

The WDS Catalog's last entry for the separation of STF 2758 AB is 30.7”, while the observed average separation was 32.2”. Our percent error for the average separation was 4.9%, which is within one standard deviation. The authors attribute the large standard deviation and large difference from the catalog value to poor sky conditions due to nearby wildfire which increased scintillation. The WDS Catalog's entry for the position angle is 152.0°, while the observed position angle was 151.4°. The percent error for the position angle was 1.39% which is also within one standard deviation. These results can be considered accurate according to Ron Tanguay, an experienced double star observer, who stated that a difference of 5% between observed and catalog values is adequate (Tanguay 1998, 2003).

Based on the results from the first star, the observers felt confident enough to measure a less studied double star. Johnson selected the double star STTA 123 AB (RA: 13h 27m 04s Dec: +64° 44m 07s) because it fit the criteria of being bright enough (magnitude 7 or less) to be easily seen through a small telescope and had similar proper motion vectors, suggesting the pair may be a binary. Table 2 presents the observational results.

Table 2: Average, standard deviation, and standard error of the mean for the observed separation and position angle of 61 STTA 123 AB.

	Separation	Position Angle
Average	69.9″	148.0°
Standard Deviation	1.8″	1.4°
Mean Error	0.6″	0.4°

The WDS Catalog's entry for the separation of STTA 123 AB was 68.9”, while the observed average separation was 69.9”. Our percent error for the average separation is 1.5% and within one standard deviation. The WDS Catalog's entry for the position angle is 147.0°, while the observed position angle was 148.0°. The percent error for the position angle is 0.7% and also within one standard deviation. We attribute the greater accuracy to the observers being more experienced and clearer sky conditions.

Analysis

Our primary goal for this project was to determine if a less studied double star (STTA 123 AB) is optical or binary in nature. We analyzed three of the properties of the two stars to determine if they were gravitationally bound: spectral type, stellar parallax, and proper motion vectors. To find these properties, the participants found both stars' HD designations in the SIMBAD database. The primary star's designation is HD 117200 and the secondary star's designation is HD 117201.

If the spectral types of the two stars in a binary system are significantly different, the more luminous star should have a lower apparent magnitude. However, if the spectral type is the same, the apparent magnitude should be similar. The spectral type of the primary star is F0 and its magnitude is 6.6. The spectral type of the secondary star is also F0 and its magnitude is 7.0. Since the stars have the same spectral type and the difference in magnitude is only 0.4, the stars are probably a similar distance away from Earth.

To quantify this observation, the students used stellar parallaxes to calculate the distance to each star in light years. The distance to a star in parsecs is equal to the reciprocal of the parallax in arc seconds. The distance in parsecs is multiplied by 3.26156 (the number of light years in a parsec) to find the distance in light years. The parallax for the primary star is 0.01483” ± 0.00055”. This corresponds to a distance of 220 light years. The parallax of the secondary star is 0.01530” ± 0.00059”. This corresponds to a distance of 213 light years. The minimum distance to the primary star is 212 light years and the maximum distance to the secondary star is 222 light years. Therefore, the difference between these two distances is well within the parallax errors.

It is most likely that a double star is binary if the proper motion vectors of the two stars are within 10% of each other (Arnold 2010). Table 3 shows the proper motion vectors for the primary and secondary stars. The difference between the proper motion vectors of the primary and secondary is 2.9%.

Table 3: Proper Motion Vectors for STTA 123 AB.

	Right Ascension (mas/yr)	Declination (mas/yr)
Primary Star	-68.76	35.16
Secondary Star	-69.74	34.62

Preliminary Orbit Calculation

Because the separation and position angle have not changed significantly since the first observation in 1876, a circular orbit could be assumed. The masses of the two stars in solar masses (M_1 and M_2), their separation in astronomical units (A), and their period in years (P) can be calculated using Newton's modification of Kepler's third law:

$$M_1 + M_2 = A^3/P^2$$

$$1.4 + 1.4 = 316^3 / P^2$$

Since both stars have the spectral type F0, their masses can be estimated to be 1.4 $M_\odot$ based on the Hertzsprung-Russell diagram. This can only be done if the stars are on the main sequence where there is a strong correlation of luminosity and mass. If both stars are assumed to be the same distance from Earth, the distance between the two stars can be calculated by dividing the cosine of the separation in degrees (0.00319°) by the mean distance to the stars (216.5 light years). This equates to a separation of about 0.005 light years (316 AU). The equation yields a period of about 3357 years. This long orbit is expected as the separation and position angle appear to have changed little since the double star was first observed in 1876. The first reported separation was 68.9" and the first reported position angle was 147°, both within the standard deviation of the present study.

However, the similarity between the first observations and present observations are slightly suspect. Even with such a large orbit, a shift of at least 14° should have been seen in the last 134 years if the orbital plane is oriented at 90° to our line of sight. If the 1° shift in position angle is real, the orbit should be on the order of 48,000 years which is inconsistent with the calculated distance between them. Thus, the authors offer four suggestions to account for the discrepancy between the observed and calculated position angles: 1) The secondary star has actually been ejected from the system and is now moving linearly away from the primary such that there should be no significant shift in position angle; 2) The orbital plane has a minimal inclination to our line of sight and the secondary star is moving either toward Earth or away from Earth relative to the primary; 3) The orbit is not circular and the secondary is near greatest elongation from the primary; or 4) The orbit is both inclined and eccentric.

According to double star observer Paul Couteau (1981), an eccentricity correction factor of 1.25 can be applied to most binary star systems to account for elongated orbits. For STTA 123 AB, this would equate to a semi-major axis of 395 AU and a period of 4691 years. However, a change in position angle of at least 10° would still be expected over 134 years. Thus, the authors believe the orbit is also inclined to our line of sight, decreasing the expected change in position angle. Future researchers may determine the true eccentricity and inclination of the orbit.

Conclusions

The participants analyzed a double star to determine if it is likely to be an optical or binary pair. Because the stars have similar apparent magnitudes and spectral types, they are probably a similar distance from Earth. To confirm that this is likely, the participants calculated the distances to the stars using stellar parallaxes obtained from the SIMBAD database. The difference in the calculated distances were within the error of the stellar parallaxes. Furthermore, the proper motion vectors of the two stars are similar enough to suggest they are moving through space together. Thus, the participants conclude that the double star STTA 123 AB is likely a binary system.

Johnson then calculated a preliminary circular orbit and determined the masses of the two stars along with their separation in astronomical units and period in years. Currently, STTA 123 AB only has 23 reported observations in the WDS Catalog. Because the system is likely binary, it is deserving of further study to resolve its orbit.

Arnold then studied the calculated orbit and predicted what the observations should be. A discrepancy was found in that the position angle should have shifted by at least 14°, yet it has not significantly changed. The authors suggest that the orbit is eccentric and inclined to our line of sight such that the position angle has not significantly changed. This would make the orbit a level 5 according to the Sky Catalog 2000 description where this is a rough or preliminary orbit that may be useful to future researchers. Alternatively, there is a chance that the stars are very close together in space but are not in a binary system and future observers will see linear motion.

Over the course of the three day workshop, the students took quantitative measurements of two double stars, one well known and one much less known. The students also calculated the average, standard deviation, and standard error of the mean, and included their observations in a scientific paper. Through this process, the observers learned a technique for measuring double stars with an astrometric eyepiece. What they learned can be taken back to Evergreen State College and taught to other students.

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